DISTRIBUTION AND CONSERVATION OF *PLETHODON* SALAMANDERS ON FEDERAL LANDS IN SISKIYOU COUNTY, CALIFORNIA

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ABSTRACT—The Northwest Forest Plan is a large-scale ecosystem management plan that establishes a system of federal reserves interspersed with matrix forestlands where timber and other commodity production are given priority. Generally, management on reserved lands attempts to protect species associated with older forests. Whereas management in matrix lands emphasizes timber production, it maintains some protections for species associated with older forests. We conducted surveys at randomly selected points within the range of the Scott Bar Salamander (*Plethodon asupak*) and the southern portion of the range of the Siskiyou Mountains Salamander (*P. stormi*). We conducted surveys on both reserved and matrix lands to assess the relative role that these allocations play in the long-term persistence of *Plethodon* salamanders in this region. At low elevations (<1219 m), the proportion of sample points with captures of *Plethodon* spp. was significantly higher in matrix lands than on reserved lands. However, the number of *Plethodon* spp. captured at matrix and reserved land points was similar. Matrix land mitigations may be essential to provide protection for salamanders with small ranges and limited dispersal abilities. Oregon Ensatina (*Ensatina eschscholtzii*), the 2nd most commonly encountered amphibian, was more evenly distributed across the landscape than *Plethodon* spp. and was not associated with either reserved nor matrix lands.

Key words: California, conservation, distribution, Oregon Ensatina, *Ensatina eschscholtzii*, Northwest Forest Plan, *Plethodon asupak, Plethodon stormi,* reserves, Siskiyou County, Scott Bar Salamander, Siskiyou Mountains Salamander

The conservation value of forest reserves has been a point of discussion in the US Pacific Northwest for over a decade and, although there are numerous desirable conservation attributes of large-scale reserves (Schwartz 1999), their utility is limited for rare species whose distributions do not coincide with reserved lands (Noss 1987). In 1994, the US Northwest Forest Plan was developed as a landscape-scale management plan covering approximately 9.7 million ha of federal lands in Washington, Oregon, and northern California. The plan created a system of reserves where protection of late-successional forests was given management priority. The reserves created by the Northwest Forest Plan are composed of congressionally designated wilderness areas, late-successional reserves, and riparian reserves. Generally, management in late-successional and riparian reserves attempts to protect species associated with older forests. Together these reserves include approximately 80% of federal lands within the Northwest Forest Plan area. Matrix lands constitute the remaining portion of the landscape where timber and other commodity production is given priority (USDA and USDI 1994). The system of reserved lands was designed to maintain well-distributed populations of the Northern Spotted Owl (*Strix occidentalis*) and was assumed to provide for the persistence of other late-successional and old-growth forest associated species. However, populations of species with small ranges, limited mobility, or both, often function at a much finer scale than wide-ranging, highly mobile organisms such as the Northern Spotted Owl. Questions about the long-term persistence of several hundred species of animals, plants, bryophytes, lichens, and fungi associ-

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ated with late-successional forests led to the inclusion of species-specific mitigations in the Northwest Forest Plan. These mitigations, known collectively as ''Survey and Manage'', included specific management direction within the known or suspected range of the Siskiyou Mountains Salamander (*Plethodon stormi*) and required pre-project surveys and known site protection (USDA and USDI 2001). Subsequent to the design and implementation of the Northwest Forest Plan, populations of *Plethodon* were discovered south of the Klamath River that were later described as *P. asupak,* the Scott Bar Salamander (Mead and others 2005a). The Survey and Manage mitigations proved to be controversial (Molina and others 2006) and the two main land management agencies governed by the Northwest Forest Plan, the Bureau of Land Management and the US Forest Service, have eliminated the Survey and Manage mitigations (USDA 2007; USDI 2007).

Plethodon stormi and *P. asupak* are terrestrial forest salamanders that occur in cool, moist microhabitats associated with rocky substrates (Clayton and Nauman 2005; Mead and others 2005b; Welsh and others 2007). Populations of *P. stormi* and *P. asupak* appear to reach their highest densities in forests with closed canopies and rocky soils on north-facing slopes (Nussbaum and others 1983). Both species have restricted distributions limited to portions of the Siskiyou Mountains of southern Oregon and northern California. The range of *P. stormi* is only about 136,000 ha and that of *P. asupak* is much smaller, about 23,000 ha, based on the 17 locations currently known (Petranka 1998; Clayton and Nauman 2005; Mead and others 2005a; Mead 2006). Both species appear to be adversely affected by timber harvest and other land management activities (Mead and others 2005b; Clayton and Nauman 2005; Welsh and others 2007).

The federal late-successional reserves, built around existing congressionally withdrawn lands (designated Wilderness Areas and National Parks), were designed to provide large blocks of habitat for northern spotted owls. However, they may not provide adequate protection to other older-forest associated species whose ranges have limited overlap with those reserves or whose life history traits occur at a different scale than the Northern Spotted Owl (e.g., physical size, home range, method of dispersal; Thomas and others 1993). To assess the relative role that the federal reserve system plays in providing for the long-term persistence of *P. stormi and P. asupak* in northern California, we conducted a stratified random survey for terrestrial salamanders on federal lands and compared occupancy rates and abundances between reserve and matrix land allocations.

METHODS

The study area encompassed 121,000 ha in western Siskiyou County, California, in the Klamath-Siskiyou bioregion (Fig. 1), which included all known sites of *P. stormi* south of the Siskiyou Mountains crest and all known localities of *P. asupak.* Because the distributions of *P. stormi* and *P. asuapk* were not well delineated along the eastern edge of their ranges during our study design phase, areas beyond the eastern edge of the known range were included if they were thought to have sufficient precipitation to support these salamanders. In the southeast, the study area was limited by the extent of federal lands. The northern edge of our project area was the boundary between the Klamath and Rogue River-Siskiyou National Forests.

The study area is dominated by steep, rugged terrain and has long, hot summers with precipitation largely limited to November through April. The Klamath River and its tributary the Scott River flow at the bottom of deep canyons that bisect the study area. Elevation ranges from approximately 330 m at Happy Camp, California, to >2500 m on the higher peaks. The terrain produces a gradient in precipitation from >2000 mm/y in the northwestern corner of the study area to 500 mm/y in the eastern portion of the study area in the rain shadow of the Marble Mountains (data from the Oregon Climate Service: http://www.ocs.orst.edu/prism/prism_products.html; Fig. 2). Precipitation falls primarily as snow at elevations above 1300 m and as rain at lower elevations. Within the study area, striking elevation gradients in abiotic conditions and plant communities extend from the bottom of river canyons with hot, dry oak woodlands to alpine parklands and cold, windy ridges.

We selected survey points using a stratified random design with federal land allocations (matrix and reserved) as strata. We overlaid a grid consisting of 0.4 × 0.4-km cells on a map

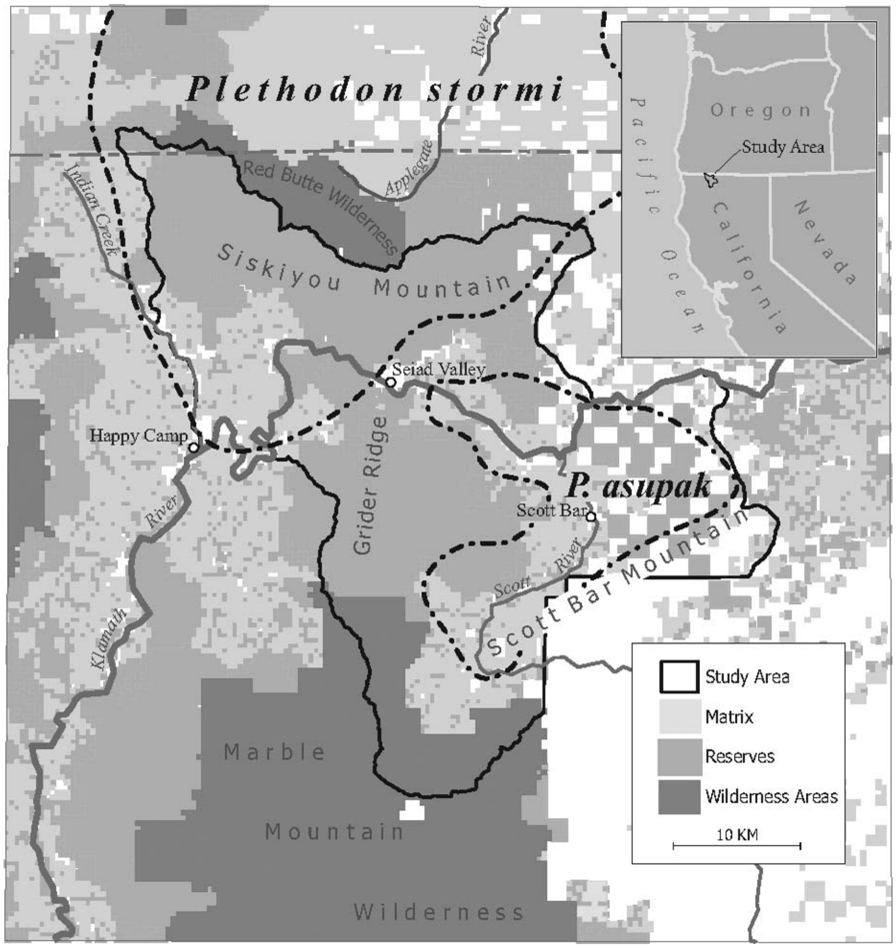

FIGURE 1. Study area with federal Northwest Forest Plan land allocations and the range of *Plethodon stormi* and *P. asupak* (dashed lines). The study area is outlined in black. The Marble Mountain and Red Butte Wilderness areas, part of the reserve system, are included for geographic reference.

of the study area. Each grid intersection (n = 7413 grid points) was numbered and the land allocation for each intersection was determined using a Geographic Information System and data from the Klamath National Forest Land Management Plan, the Northwest Forest Plan, and a preliminary map of federal riparian reserves. Federal reserved lands (n = 4255 points; 57%) included late-successional reserves, congressionally and administratively withdrawn lands such as wilderness areas, and sensitive species reserves (Fig. 1). Riparian reserves (n = 571 points) represented 8%, and matrix lands (n = 1556) represented 21% of the points. For analysis, we included points that occurred within federal riparian reserves in the reserved set. Private land was not included in the sample (n = 1027 points; 14%), and 4 points had no data regarding land allocation, resulting in a population of 6382 potential federal points in the sampling pool. We randomly selected reserved (n = 61) and matrix (n = 21) land points in approximate proportion to their abundance on Klamath National Forest lands in the study area. Due to access problems at higher elevations resulting from snow conditions and limited road or trail access, we further stratified by the elevation threshold below which complete sampling of the random points was possible. Whereas the known elevation range for *P. stormi* is 488 to 1830 m (Clayton and Nauman 2005), site occupancy by these salamanders north of

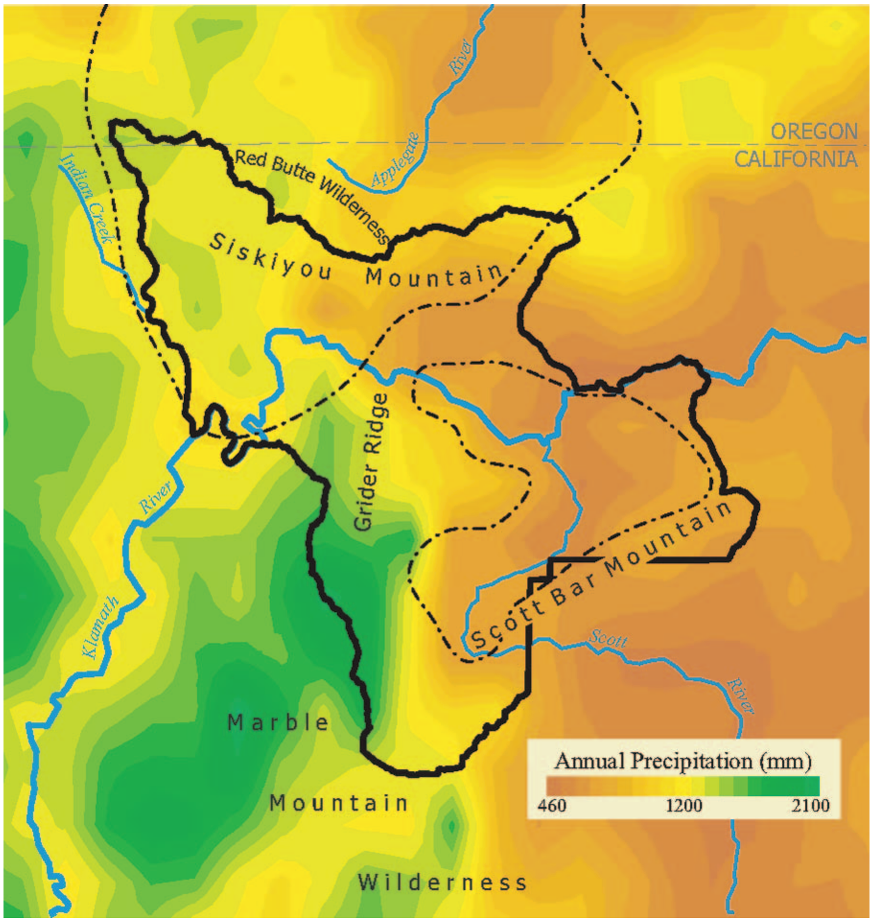

FIGURE 2. Precipitation within the study area (mm/year). Data from the Oregon Climate Service (http://www.ocs.orst.edu/prism/prism_products.html).

the crest of the Siskiyou Mountains decreases with increasing elevation (N. Suzuki, unpubl. data). The known elevation range of *P. asupak* is about 490 to 1620 m (D. Olson and R. Nauman, unpubl. data).

Surveys were conducted between 18 February and 24 May 2003 during periods when air temperature was between 4 to 20°C, no freezing weather had occurred in the last 24 h, and substrates were moist. A 2-person field crew used a Global Positioning System to navigate to the sample location. Upon arrival, we conducted a 0.5-h reconnaissance for suitable *Plethodon* salamander habitat within approximately 350 m of the designated point to select the area for sampling that was most likely to harbor *Plethodon* salamanders. Criteria for sample site selection included the presence of emergent colluvial rock, litter depth, vegetation type, and microclimatic conditions created by topography, forest canopy, or both.

We sampled each site 1 time. We conducted a time-constrained (2 person-h) search of the site by turning rocks, wood, and occasionally plant litter. We returned cover objects to their original position. We visually estimated the extent of the area searched. All amphibians encountered were captured, measured, and released. Due to difficulties in discriminating between *P. stormi* and *P. asupak* in the field, we present a combined analysis of all *Plethodon*. We identified other amphibians to species.

The random sampling design allowed inference to be made to the population in the sampled landscape. We extrapolated the proportion of sample points with salamander cap-

TABLE 1. Amphibian captures during surveys of randomly selected sites (sample points) south of the Siskiyou Mountains crest in California.

Species	Points with detections		Number of individuals			
	n	%	Per site	Per person-h	Per m^2	Maximum per point
Plethodon stormi and *P. asupak*	18	26.1	4.77	2.39	0.011	16
Ensatina eschscholtzii	31	44.9	1.84	0.92	0.005	6
Aneides flavipunctatus	6	8.7	2.33	1.17	0.004	6
Bufo boreas	1	1.4	1.00	0.50	0.002	1

tures to estimate the number of points in our larger landscape (n = 6382 points) that we expected would result in *Plethodon* salamander detections. A standard error was calculated for each estimate using the formula $SE = N \cdot [(1 - f) \cdot ((p)(1 - p)/(n - 1))]^{1/2}$, where N = total number of points in the population, n = number of points sampled, f = n/N, and p = the proportion of n that had at least 1 detection of the target species (Thompson 2002). We used a Chi^2 two-sample test for equality of proportions with a continuity correction (SPlus, Insightful Corporation, 1999) to test the hypothesis that the proportion of points with captures of each species was the same for points in matrix and reserved allocations.

We sampled 69 points in total and sampled a mean area of 761 m^2 (s = 1092 m^2) per point. Sampling was incomplete at elevations >1219 m (hereafter higher elevations). One randomly selected matrix point and 12 reserve points were not sampled due to a snowy spring and lack of road or trail access to more remote high elevation areas. Unsampled points were significantly higher in elevation than sampled points (t-test; 69 sampled points mean = 961 m; 13 unsampled points mean = 1649 m; $t = 7.706$; $df = 80$; $P < 0.01$). Four unsampled points were >1800 m in elevation.

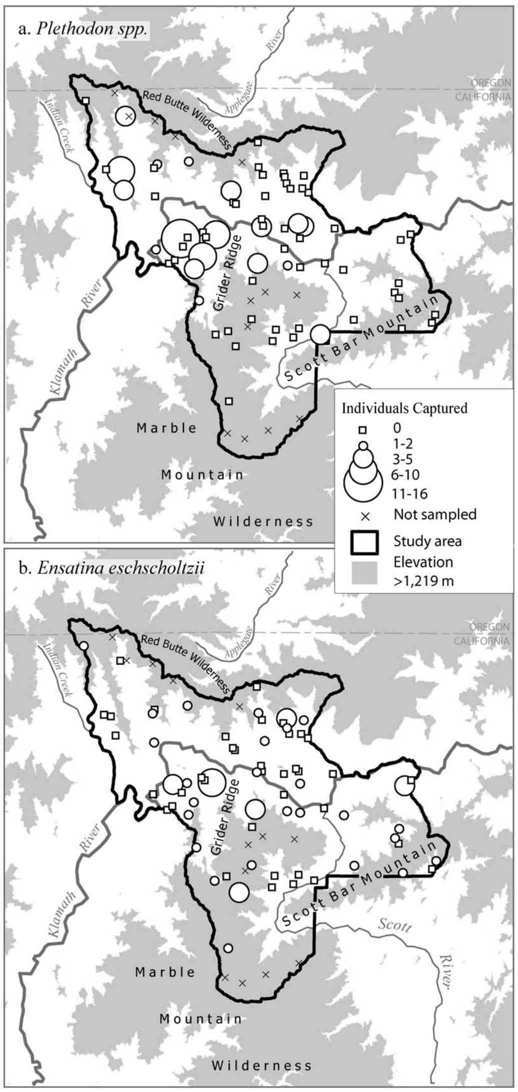

FIGURE 3. Captures of (a) *Plethodon* (*P. stormi* and *P. asupak*) and (b) *Ensatina eschscholtzii* within the study area. Areas in gray are >1219 m elevation.

RESULTS

We captured 158 individuals of 5 species of amphibians (Table 1). *Plethodon* spp. (*P. stormi* and *P. asupak* together) dominated captures (n = 86 individuals; Table 1, Fig. 3), with *Ensatina eschscholtzii* the 2nd most abundant salamander (n = 57; Table 1, Fig. 3). Together these salamanders comprised 67% of all individuals captured. However, *E. eschscholtzii* was found at more points (n = 31) than any other species. We detected *Plethodon* spp. at 18 sample points.

TABLE 2. Distribution of sample points in 4 strata and captures of *Plethodon* salamanders.

Strata						
Land allocation	Elevation (m)	Points in landscape	Points selected	Points sampled	Points with *Plethodon* (detection rate/site)	Relative abundance (captures/person-h)
Reserves	>1219	2264	24	12	4 (33%)	1.25
	<1219	2558	37	37	6 (16%)	2.83
Matrix	>1219	389	3	2	0 (0%)	0.00
	<1219	1166	18	18	8 (44%)	2.63

Aneides flavipunctatus was the only other salamander detected (14 individuals at 6 points).

At high elevations within reserved allocations, *Plethodon* spp. were captured at 4 of 12 (33%) and *E. eschscholtzii* at 8 (67%) of the points surveyed. The only other amphibian found was *A. flavipunctatus* (6 individuals at 1 point). The only amphibian detected within the matrix lands at high elevations was *E. eschscholtzii* (1 and 2 individuals per point, respectively).

At lower elevations (points <1219 m), the site occupancy rate of *Plethodon* spp. was significantly lower on reserved lands (6 of 37; 16%) than on matrix lands (8 of 18; 44%; $\chi^2 = 3.706$, $df = 1$, $P = 0.027$; Table 2). The occupancy rate of *E. eschscholtzii* was the same on matrix (8 of 18 points; 44%) as reserved lands (13 of 37; 35%; $\chi^2 = 0.1377$, df = 1, $P = 0.6442$).

For *Plethodon* spp., the number of individuals captured at sites with at least one detection at lower elevation points was similar between matrix and reserved lands (reserved = 5.67/point; matrix = 5.25/point). When *Plethodon* spp. were found they were more than twice as abundant at lower elevation points compared to higher elevation points (higher elevation = 2.5/point; lower elevation = 5.43/point) but the difference was not significant (Mann-Whitney U Test; $U = 4$, $P = 0.096$). Captures of *E. eschscholtzii* were less variable and similar for higher and lower elevation points.

Within the study area, 2558 grid points occurred on the reserved lands at lower elevations, and 1166 points occurred on matrix lands at lower elevations. Multiplying the number of grid points in each subset by the *Plethodon* salamander site occupancy rates resulted in an estimate of 409 ($s_{\bar{x}} = 153$) occupied points in reserved lands and 443 ($s_{\bar{x}} = 136$) occupied points in matrix lands. Repeating the procedure with *E. eschscholtzii* yielded 895 ($s_{\bar{x}} = 24$) and 548 ($s_{\bar{x}} = 18$) occupied points in reserved and matrix lands, respectively.

Discussion

At lower elevations, federal matrix lands appeared to have a greater role than reserved lands in supporting terrestrial salamanders. The proportion of points with *Plethodon* spp. was nearly 3 times greater on matrix lands than on reserved lands. At lower elevation points with captures, *Plethodon* spp. tended to be more abundant. Whereas not significant, matrix lands on average produced twice the number of *Plethodon* spp. than reserved lands. Lower elevation matrix lands represented 24.6% of points sampled, but we captured nearly half of all *Plethodon* on this small portion of the study area. Relative abundance of *E. eschscholtzii* on lower elevation matrix lands was only slightly higher than the relative abundance on lower elevation reserved lands.

Inference of our random sampling at low elevations yielded estimates of *Plethodon* occupancy at over 400 grid points in both reserved and matrix lands. The larger spatial extent of reserves, 75% of federal lands in the study area, suggests these 400+ reserved land occupied sites would have a different spatial pattern, either more dispersed across the broader area or potentially more clustered in more suitable habitat (such as possibly at lower elevations). In comparison, a more compressed pattern of 400+ estimated occupied points is expected on the smaller area of federal matrix lands, which covered the other 25% of the landscape. These 400+ matrix land points are also estimated to have higher abundances of *Plethodon* spp. *Ensatina eschscholtzii* occupancy estimates were about double that of *Plethodon,* again supporting their more widespread occurrence.

Riparian reserves may provide some measure of protection to terrestrial salamanders within the matrix lands. Riparian reserves are variable-width areas (15 to 125 m) that flank the sides of rivers and streams and protect unstable slopes and wetlands. Riparian reserves are embedded in matrix lands and are designed to provide a variety of benefits including refugia for forest-associated species (USDA and USDI 1996). All riparian reserve sites that we sampled were at lower elevations. *Plethodon* salamanders were captured at 2 of 9 (22%) riparian reserve points. If we treat these points as if they were occurring on matrix lands, *Plethodon* spp. captures occur on 50% of matrix land points and only on 11% of reserved land points. This further supports the relative importance of matrix lands for long-term persistence of *Plethodon* spp. in this region. By providing a network of relatively undisturbed areas throughout the intensively managed matrix lands, riparian reserves may provide important legacy habitats for old-forest associated species.

Whereas captures of *E. eschscholtzii* were relatively evenly distributed across the study area, captures of *Plethodon* spp. were concentrated along the Klamath River west of Seiad Valley. This distribution generally coincides with areas of higher rainfall (Fig. 2). Peak precipitation levels are found along the western edge of the study area, and areas to the east are increasingly xeric. Elevation in the western part of the study area also may favor terrestrial salamanders. The lowest point in the study area (approximately 325 m) is at the point where the Klamath River flows out of the study area near the town of Happy Camp, California (Fig. 1). Lower elevation areas coincide with high rainfall in the western part of the study area, producing the mild temperatures and long wet seasons where suitable habitats for terrestrial salamanders occur. Snow and freezing weather at these lower elevations is normally transitory, and salamanders are active for much of the winter (R. Nauman, pers. obs.). The majority of these wet, low elevation areas are on federal matrix lands immediately east of Happy Camp, California, north of the Klamath River (Fig. 1). A substantial portion of the study area west of Seiad Valley along both banks of the Klamath River is within reserved lands. Reserved lands in these low elevation, higher rainfall areas likely provide valuable habitat for *Plethodon* spp. In the dry eastern portion of the study area, salamander distribution becomes increasingly limited. For example, none of the 17 known *P. asupak* sites occurs on south-facing slopes (D. Olson and R. Nauman, unpubl. data).

Furthermore, the phylogeographic variation in these western plethodontids appears to mirror the complexity of forms now recognized for *Plethodon* spp. in the eastern United States (Highton and Peabody 1998). Studies of genetic variation suggest that a distinct population of *P. stormi* occurs in the western portion of the study area and warrants consideration relative to our findings. Analysis of mtDNA sequence and microsatellite DNA polymorphism places *P. stormi* from this area in a unique monophyletic group (Fig. 1; Clade II in Mead and others 2005a; DeGross 2004; Mahoney 2004); While the range of this population is small and its geographic extent is poorly defined (DeGross 2004), occupancy rates and abundances appeared to be higher in the range of this lineage than in areas farther to the east. This lineage may be at risk to persistence due to adverse effects of land management activities such as regeneration timber harvest in the block of matrix lands east of Happy Camp, whereas the reserved lands on both banks of the Klamath River west of Seiad Valley (Fig.1) may provide refugia for these salamanders. Areas east and south of Seiad Valley are drier and tend to be higher in elevation so they may not provide suitable habitats. The known distribution of *P. asupak* follows the lower elevation matrix lands along the south bank of the Klamath River eastward from Seiad Valley and south on both sides of the Scott River (Mead and others 2005a, Fig. 1). The small range and large proportion of matrix lands suggest that special consideration may be warranted for this little-known species during land management planning.

We captured 18 animals from 5 of our sample points that are likely *P. asupak* based on field identifications. Analysis of mtDNA sequence from 4 samples collected at 2 of these points confirmed our field identifications (Mead 2006). The 5 putative *P. asupak* populations are found on both matrix (n = 3) and reserved allocations (n = 2). All 5 are <1219 m in elevation. Further delineation of the range of this species would allow a more precise assessment of its conservation needs. The north side of Scott Bar Mountain likely provides the largest block of habitat for this species, but it is poorly explored.

Our understanding of the utility of the federal Northwest Forest Plan reserved and matrix lands for protection of endemic species such as *P. stormi* and *P. asupak* is limited. Whereas *P. stormi* was the most frequently encountered amphibian species during our surveys, and was apparently locally abundant, its small range has been subject to a wide variety of disturbances including historic and ongoing mining, timber harvest, wildfire, rock quarrying and road building. The complexity of genetic structure among populations suggests limited gene flow between populations in the area (DeGross 2004); these *Plethodon* species appear to be organisms of relatively low mobility. Assessing the status of these species remains problematic, and successful conservation planning will likely require consideration of the geographic distribution of unique lineages, current occupancy and abundance patterns, and lands protected from activities potentially harmful to salamanders. Existing federal reserves would certainly contribute to long-term *Plethodon* species persistence, but our data showing higher federal matrix land occupancy rates and abundances cast a shadow of uncertainty on whether reserves alone may suffice in this regard. The role of finer-scale approaches such as managing sites in matrix lands can target areas with high occupancy and abundances, and unique lineages.

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Literature Cited

Clayton D, Nauman RS. 2005. Siskiyou Mountains Salamander: *Plethodon stormi* Highton and Brame. In: Jones LLC, Leonard WP, Olson DH, editors. Amphibians of the Pacific Northwest. Seattle, WA: Seattle Audubon Society. p 136–139.

DeGross DJ. 2004. Gene flow and the relationship of *Plethodon stormi* and *P. elongatus* assessed with 11 novel microsatellite loci. [thesis]. Corvallis, OR: Oregon State University. 53 pp.

Highton R, Peabody RB. 1998. Geographic protein variation and speciation in salamanders of the *Plethodon jordani* and *Plethodon glutinosus* complexes in the southern Appalachian Mountains with the description of four new species. *In* Bruce RC, Jaeger RG, and Houck LD, editors. The Biology of Plethodontid Salamanders. New York, NY: Kluwer Academic/Plenum Publishers. p 31–94.

Mahoney MJ. 2004. Molecular systematics and phylogeography of the *Plethodon elongatus* species group: combining phylogenetic and population genetic methods to investigate species history. Molecular Ecology 13:149–166.

*Mead LS. 2006. Plethodon salamanders of the Applegate, Klamath and Scott River Areas: Report on genetic variation and species status. Yreka, CA: US Fish and Wildlife Service. 27 pp. Available from: US Fish and Wildlife Service, 1829 South Oregon Street Yreka, California 96097. (unpublished report)

Mead LS, Clayton DR, Nauman RS, Olson DH, Pfrender ME. 2005a. Newly discovered populations of salamanders from Siskiyou County California represent a species distinct from *Plethodon stormi.* Herpetologica 61:158–177.

Mead LS, Nauman RS, Clayton D. 2005b. Scott Bar Salamander, *Plethodon asupak* Mead. In: Jones LLC, Leonard WP, Olson DH, editors. Amphibians of the Pacific Northwest. Seattle, WA: Seattle Audubon Society. p 118–119.

Molina R, Marcot BG, Lesher R. 2006. Protecting rare, old-growth, forest-associated species under the Survey and Manage Program Guidelines of the Northwest Forest Plan. Conservation Biology 20:306–318.

Noss, RF. 1987. From plant communities to landscapes in conservation inventories: a look at the Nature Conservancy (USA). Biological Conservation 41:11–37.

Nussbaum RA, Brodie ED Jr, Storm RM. 1983. Amphibians & Reptiles of the Pacific Northwest. Moscow, ID: University of Idaho Press. 332 pp.

Petranka JW. 1998. Salamanders of the United States and Canada. Washington DC: Smithsonian Institution Press. 587 pp.

Schwartz MW. 1999. Choosing the appropriate scale of reserves for conservation. Annual Review of Ecology and Systematics 30:83–108

* Unpublished.

THOMAS JW, RAPHAEL MG, ANTHONY RG, FORSMAN ED, GUNDERSON RS, HOLTHAUSEN RS, MARCOT BG, REEVES GR, SEDELL JR, SOLIS DM. 1993. Viability assessments and management considerations for species associated with late-successional and old-growth forests in the Pacific Northwest: the report of the scientific analysis team. Portland, OR: US Department of Agriculture Forest Service. 530 pp.

THOMPSON SK. 2002. Sampling. Second edition. New York, NY: John Wiley & Sons. 400 pp.

[USDA] US DEPARTMENT OF AGRICULTURE. 2007. Record of Decision to Remove the Survey and Manage Mitigation Measure Standards and Guidelines from Forest Service Land and Resource Management Plans within the Range of the Northern Spotted Owl. Portland, OR: USDA Forest Service, Region 6. 46 pp.

[USDA and USDI] US DEPARTMENT OF AGRICULTURE and US DEPARTMENT OF INTERIOR. 1994. Record of decision for amendments to Forest Service and Bureau of Land Management planning documents within the range of the northern spotted owl and standards and guidelines for development of habitat for late-successional and old-growth forest related species within the range of the northern spotted owl. Portland, OR: USDA Forest Service, Region 6. [irregular pagination]. Available at: http://www.reo.gov/s-m2006/. Accessed 10/22/07.

[USDA and USDI] US DEPARTMENT OF AGRICULTURE and US DEPARTMENT OF INTERIOR. 1996. Riparian Reserve Evaluation Techniques and Synthesis. Module of the Guide to Watershed Analysis. Portland, OR: Riparian Reserve Technical Team, Regional Ecosystem Office. 42 pp.

[USDA and USDI] US DEPARTMENT OF AGRICULTURE and US DEPARTMENT OF INTERIOR. 2001. Record of decision and Standards and Guidelines for Amendments to the Survey and Manage Protection, and other mitigation measures standards and guidelines. Portland, OR: USDA Forest Service, Region 6. 145 pp. Available at: http://www.reo.gov/s-m2006/. Accessed 10/22/07.

[USDI] US DEPARTMENT OF INTERIOR. 2007. Record of Decision to Remove the Survey and Manage Mitigation Measure Standards and Guidelines from Bureau of Land Management Resource Management Plans within the Range of the Northern Spotted Owl. Portland, OR: Bureau of Land Management Oregon State Office, 44 p.

WELSH HH JR., STAUFFER H, CLAYTON DR, OLLIVIER LM. 2007. Strategies for modeling habitat relationships of uncommon species: an example using the Siskiyou Mountains Salamander (*Plethodon stormi*). Northwest Science 81:15–36.

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